Development of Feedhorn-coupled Microwave Kinetic Inductance Detectors

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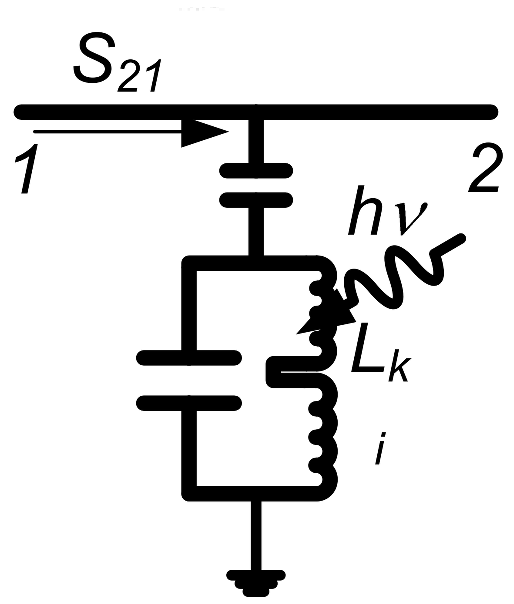
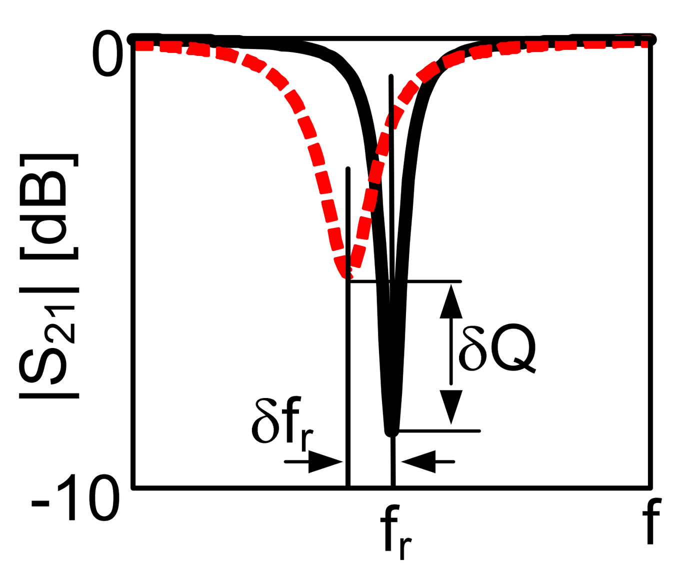
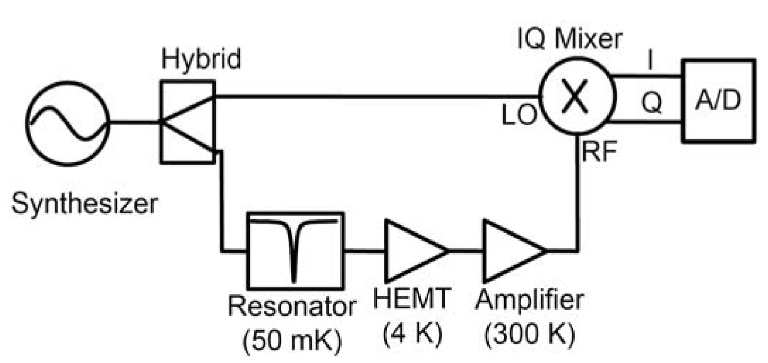
motivation

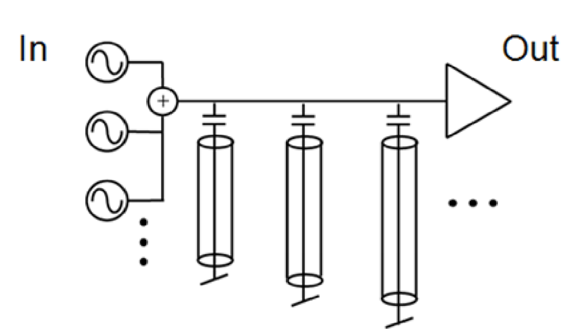
Future satellite missions operating at far infrared (FIR) wavelengths will require high sensitivity focal plane arrays. NIST has a strong background in developing FIR detector arrays as evidenced by the delivery of the 10,000 pixel imager for the SCUBA-2 instrument on the James Clerk Maxwell Telescope. We are now developing arrays of feedhorn-coupled microwave kinetic inductance detectors (MKIDs) with the goal of achieving photon-noise limited sensitivity and low-frequency stability over the range of loading conditions suitable to sub-orbital and satellite-based observations. Current efforts are focused on photometric applications with dual-polarization sensitivity at $\lambda = 250\ \mu m - 500\ \mu m$. This detector architecture will be deployed on the next-generation BLASTPol experiment, a NASA-funded balloon-borne polarimeter. However, we are also interested in exploring applications that require total intensity detection or spectroscopy.

detection in MKIDs



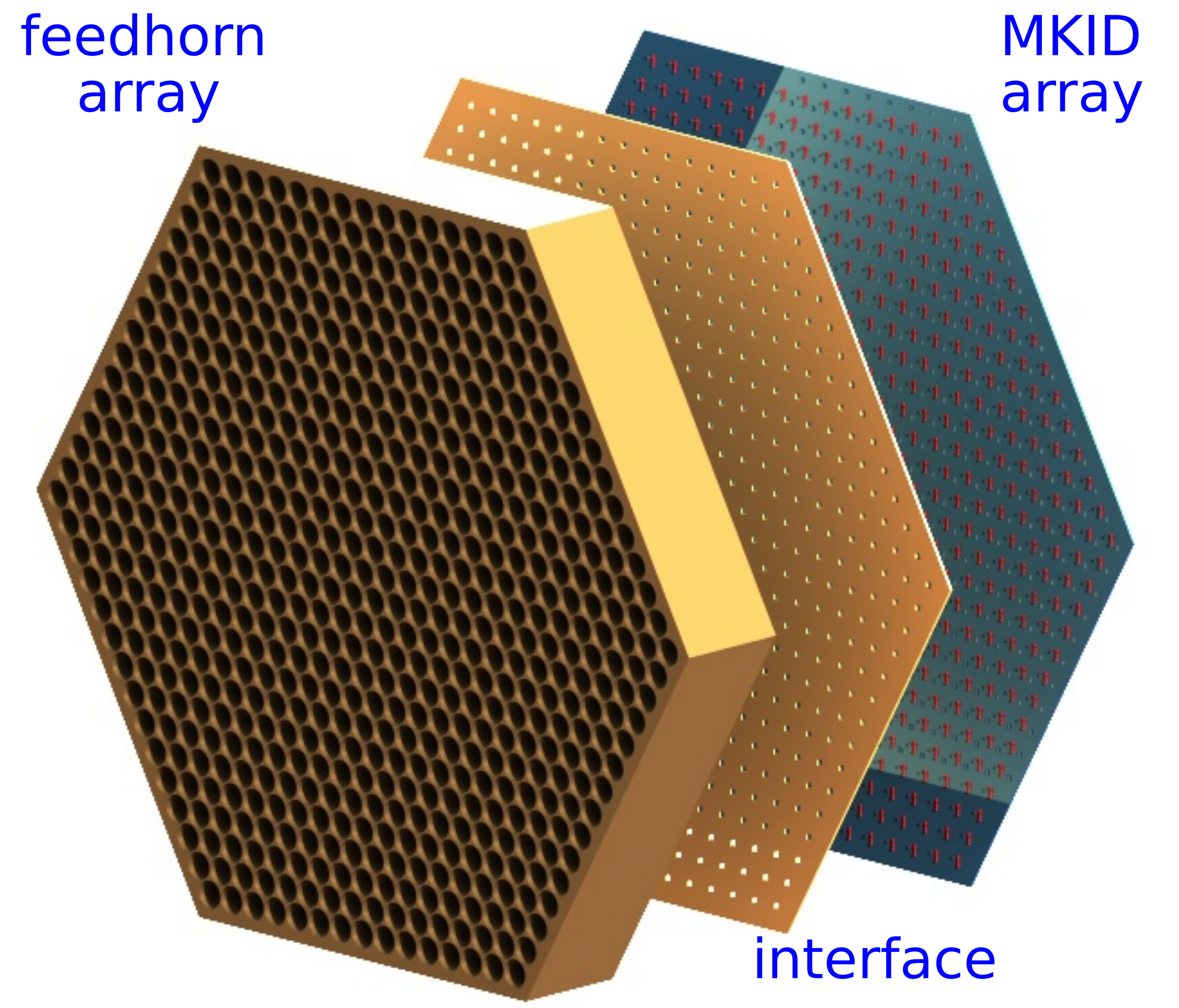




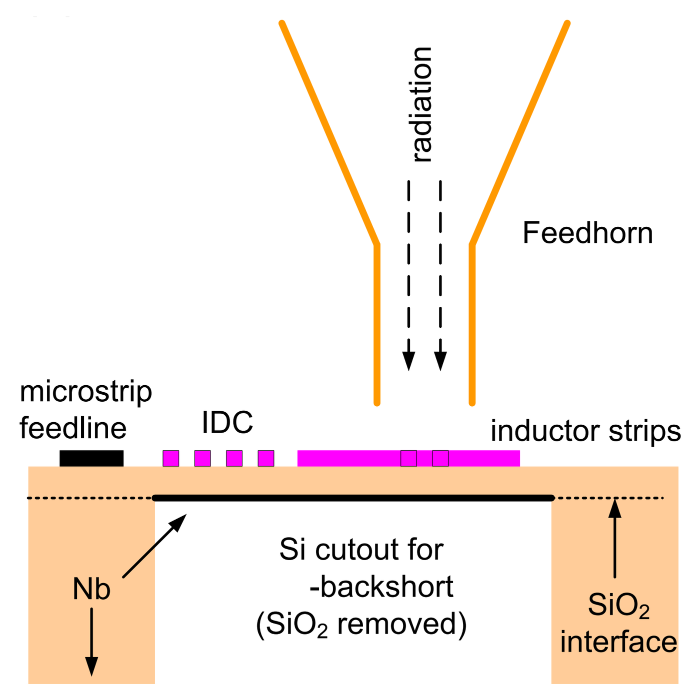


MKID are superconductors lithographically patterned into resonant circuits. FIR photons absorbed in the superconductor change the frequency and amplitude of the resonant circuit. These quantities are determined by homodyne measurement. Many MKIDs can be multiplexed on a single transmission line.

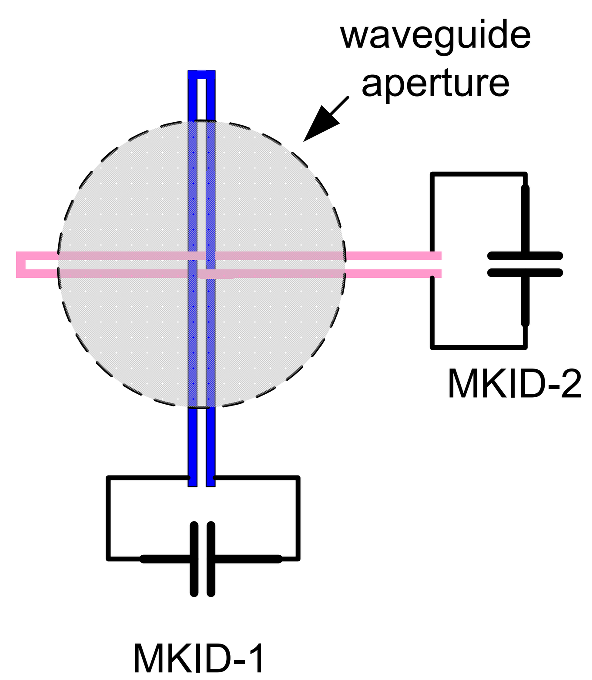
concept: feedhorns + MKIDs



Feedhorn array (either metal or based on Si-platelets) couples to a detector wafer containing ~ 1000 MKIDs through a coupling Si wafer.

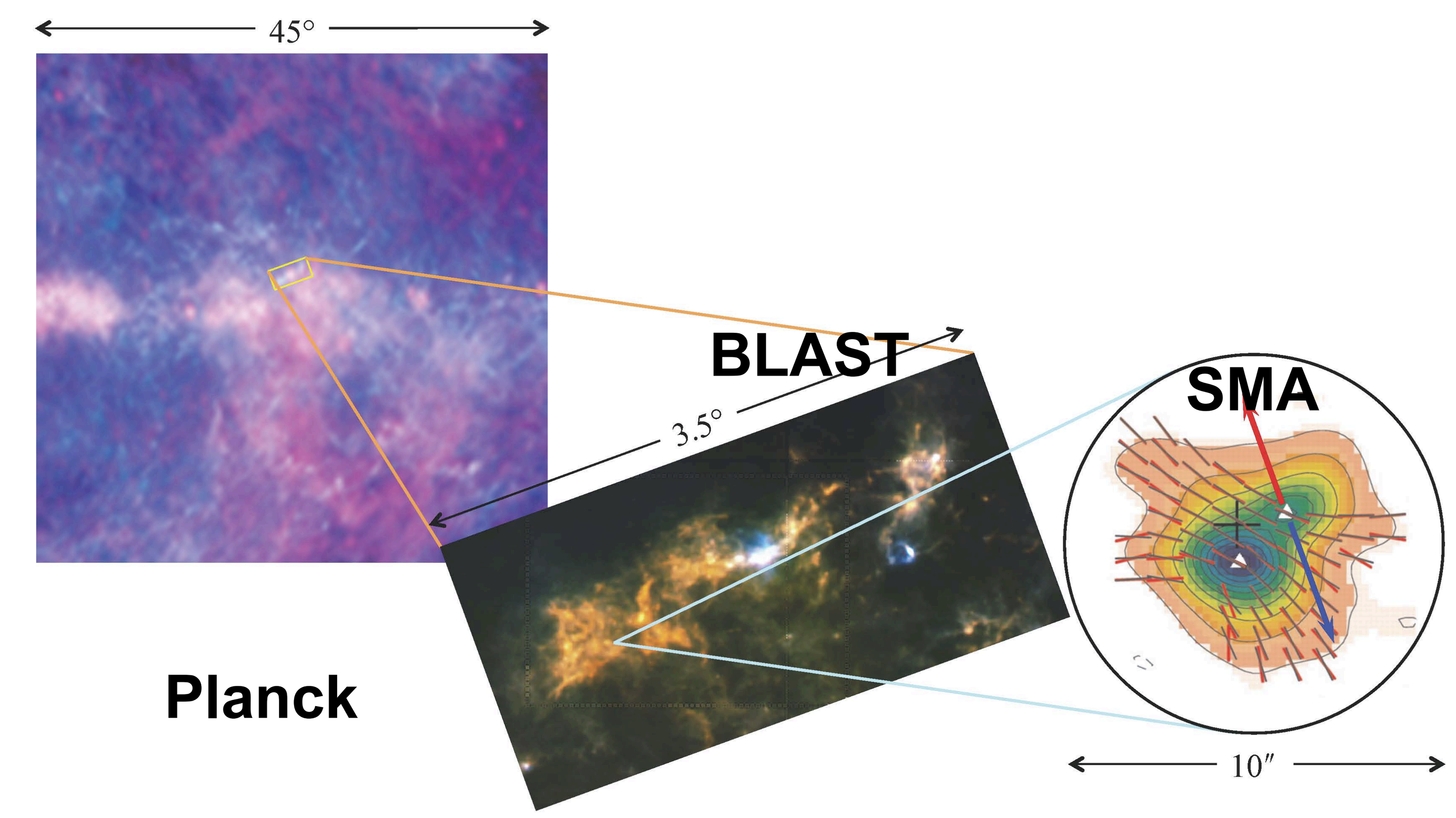


Cross-section schematic of single feed coupled to detector.

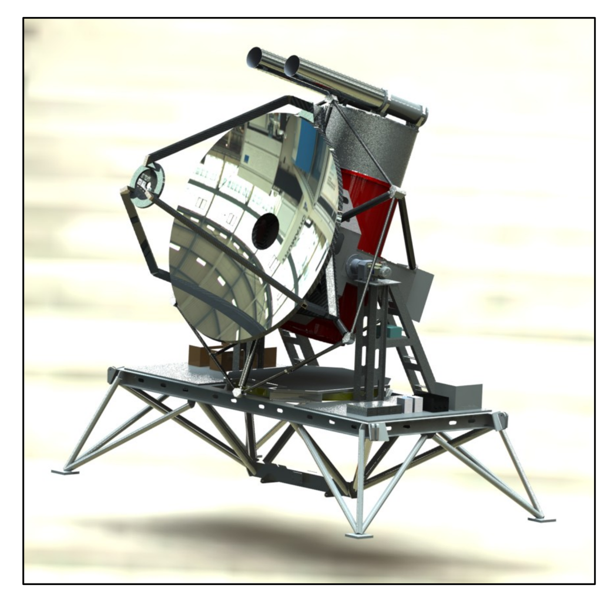


Face-on schematic of two lumped-element MKIDs, which are sensitive to orthogonal components of linear polarization.

application: next-generation BLAST



BLAST's combination of sensitivity, resolution, and mapping speed will bridge the gap between Planck and ALMA, linking core magnetic fields to the Galactic field.



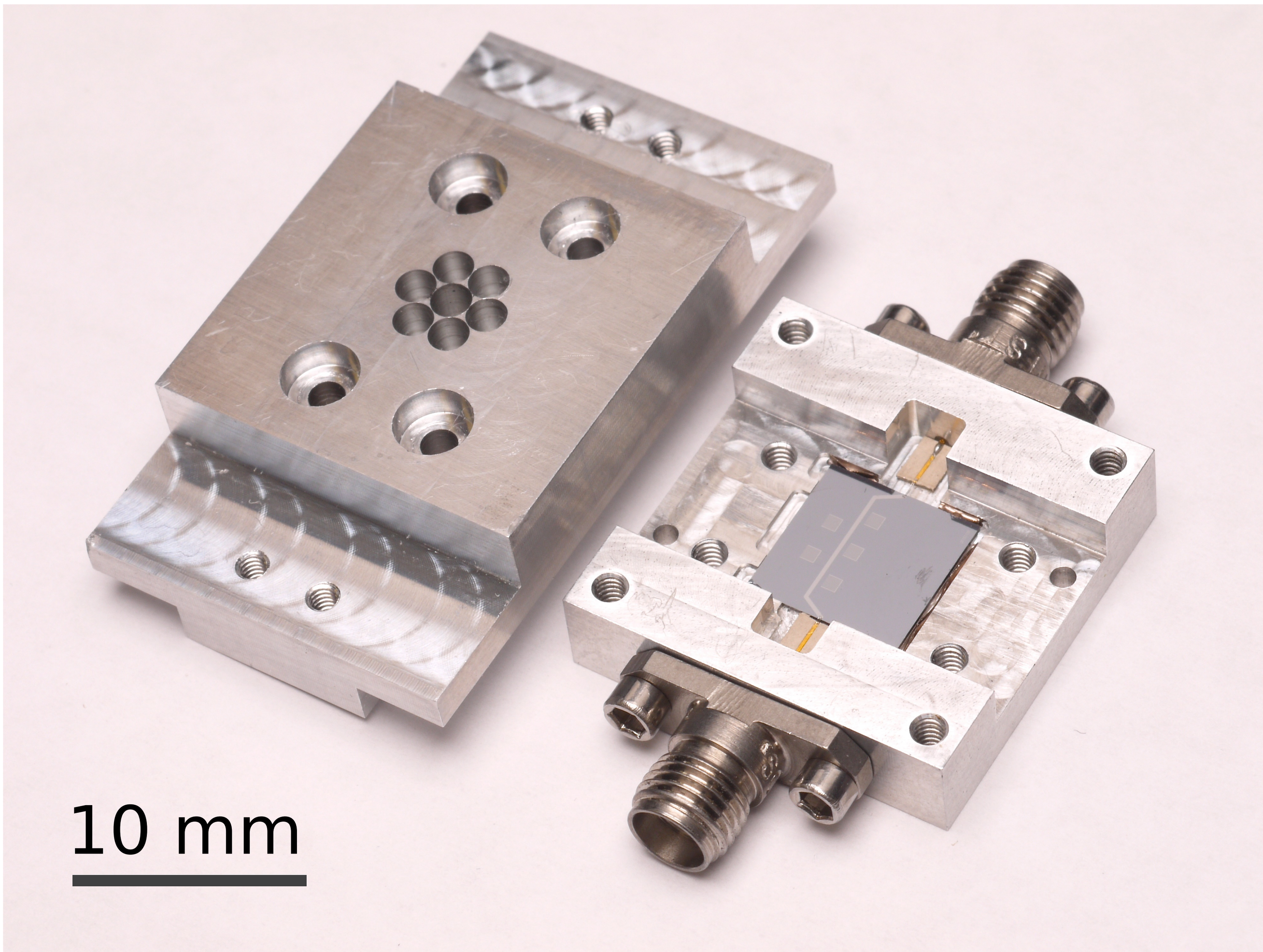
BLAST instrument

Detector count

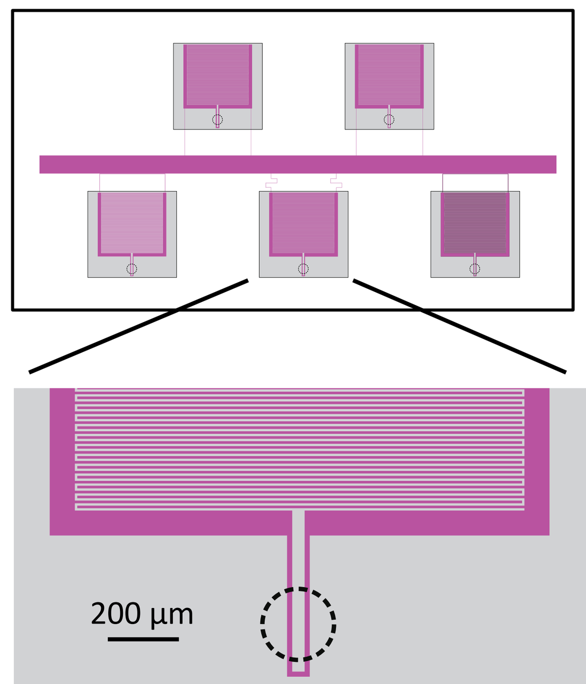
λ (μm)	$\Delta\nu/\nu$ (%)	$N_{detectors}$	P_{load} (pW)	NEP_{photon} (aW/$\sqrt{Hz}$)
250	30	1180	17	170
350	30	490	12	120
500	30	330	9	87

- Balloon-borne experiment; 28-day Antarctic flight in 2016
- Map magnetic fields in star forming regions by measurement of polarized dust emission
- 150 hours shared risk observing time

250 μm sub-array



Photograph of a 5-pixel sub-array mounted in a sample holder, which couples to a 7-pixel close-packed feed-horn array.

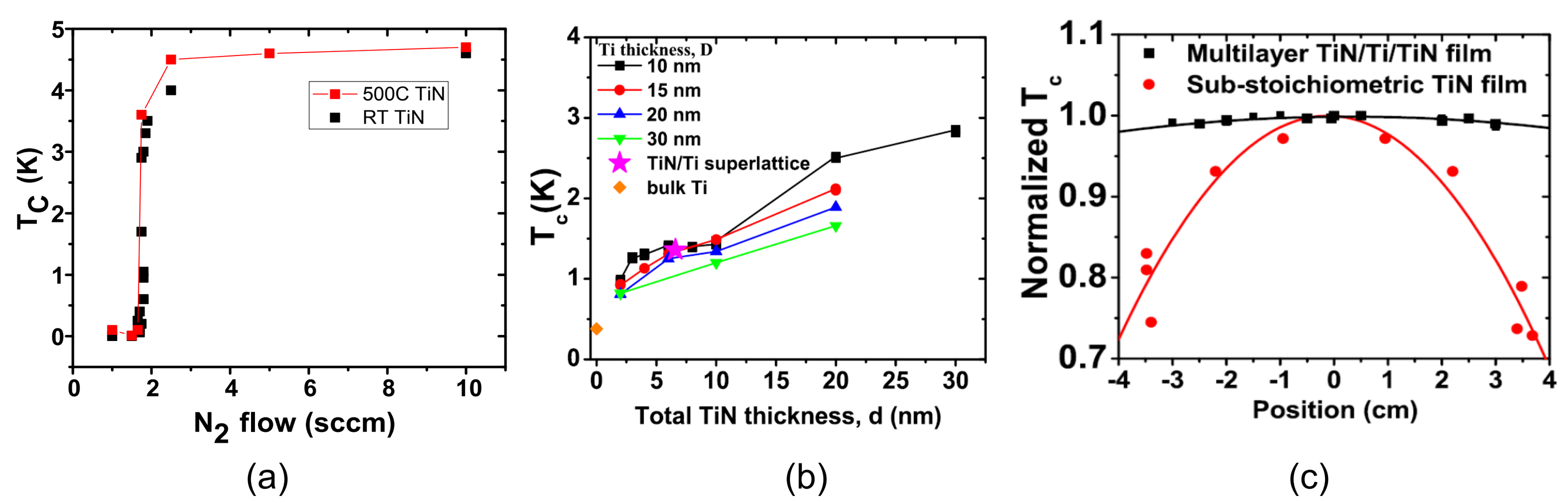


MKID design with zoom-in showing the absorbing volume within the waveguide.

Detector details

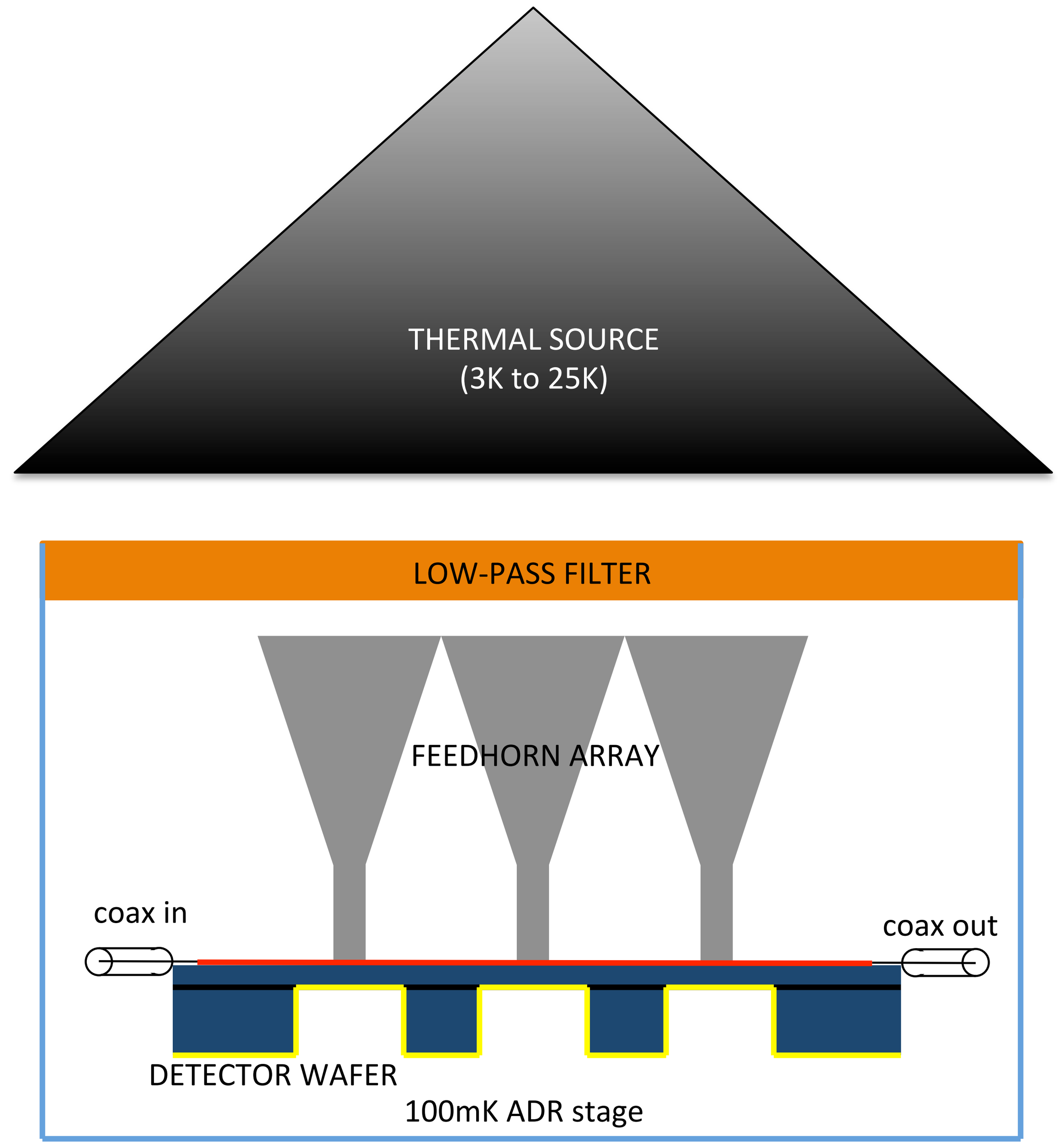
Parameter	Value
material	TiN/Ti/TiN trilayer
f_o	850 MHz
T_c	1.4 K
Q_i	200k–400k
Q_c	$\sim$ 30k
V	80 μm^3
$A_{capacitor}$	0.9 mm^3
optical band	1.0–1.4 THz

New superconducting material: TiN/Ti/TiN trilayer



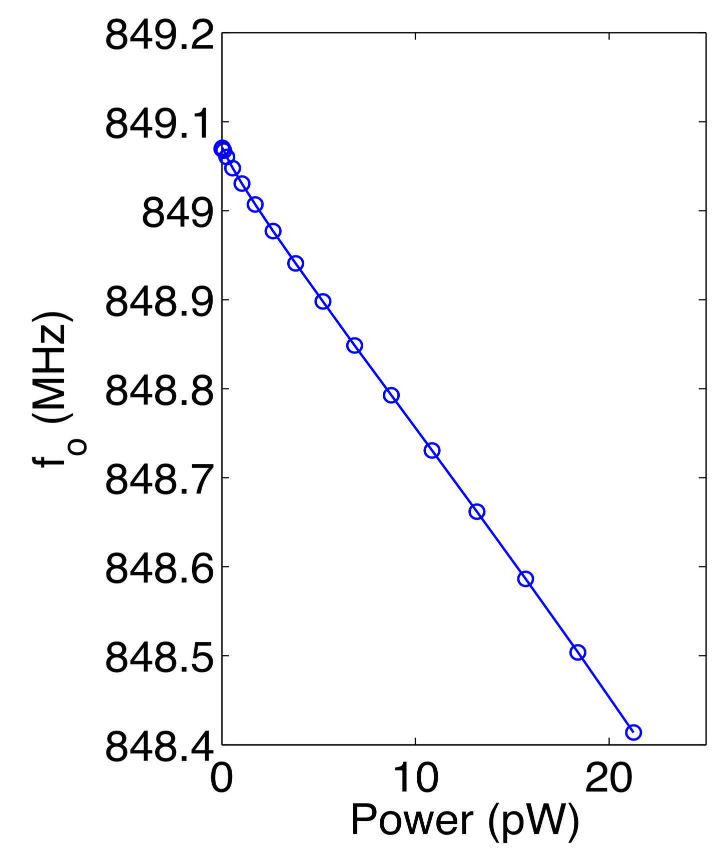
(a) TiN has a tuneable T_c. (b) T_c can also be tuned by varying layer thicknesses of TiN and Ti. (c) TiN/Ti/TiN trilayer shows better than 1% T_c uniformity across a 75 mm diameter wafer.

experimental configuration



Measurement schematic of coupling the detector sub-array to a variable temperature thermal load. The passband is from 1.0–1.4 THz.

response to thermal load

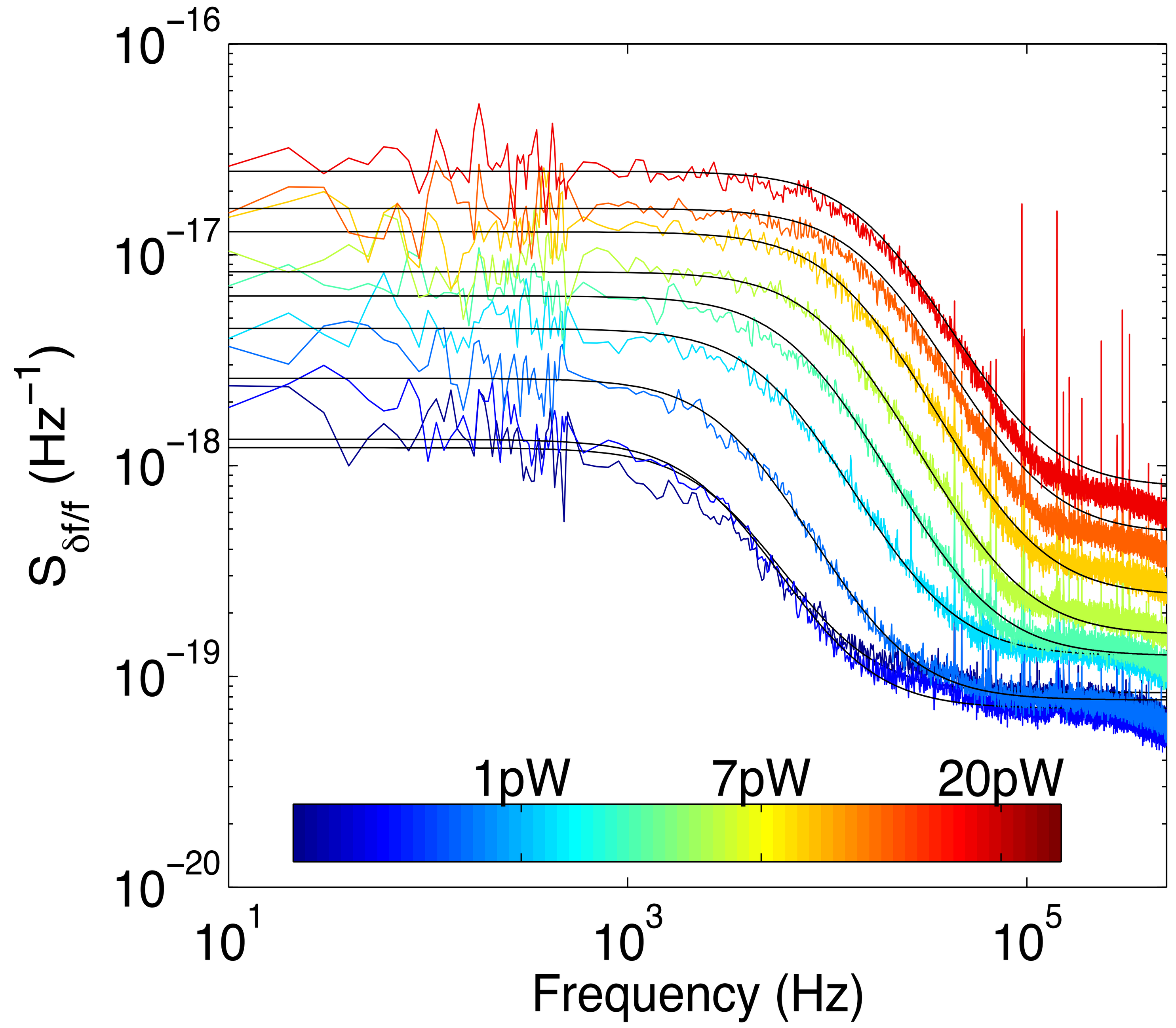


Frequency response is linear with applied thermal load.

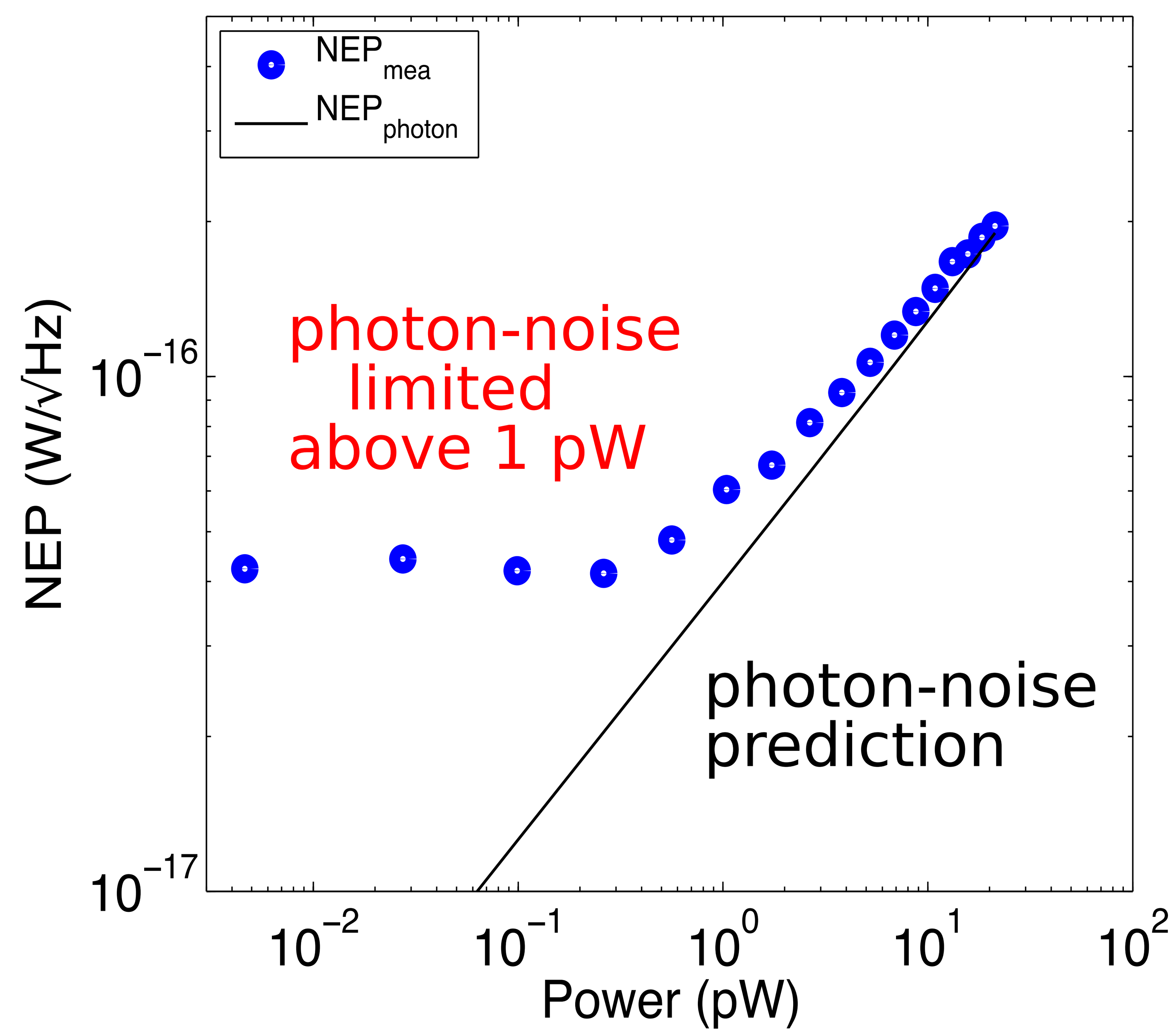
also see:

"The Next Generation BLAST Experiment"

photon-noise limited sensitivity



Noise spectra (using frequency readout) at various thermal loads.



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